BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D.C. 20024

B70 03068

SUBJECT: A Cislunar Shuttle
Case 103-8

DATE: March 23, 1970

FROM: G. T. Orrok

ABSTRACT

It is shown that a shuttle orbiter can be sized for high energy missions, in particular, missions from low Earth orbit to synchronous equatorial orbit or low lunar parking orbit and return. Aerodynamic braking gives a clear advantage over purely propulsive reusable vehicles such as the LM/B space tug. To improve mass fraction and reduce total launched weight, a vertical landing, ballistic vehicle is preferred over an "aircraft type" lander. In this case, the vehicle is potentially useful as a shuttle from lunar parking orbit to the surface as well.

This class of vehicle appears worthy of study, particularly in an evolutionary program. The higher entry velocity, for instance, is not unreasonable if early shuttles have replaceable heat shields. The multiple use of the vehicle keeps a complete cislunar capability for manned flight pending the development of more specialized vehicles. Before the space station, the shuttle can be used in Earth orbit to support activities such as satellite launch and up-down payloads which are not readily feasible for Skylab.

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MEMORANDUM FOR FILE

Previous studies have examined lunar missions for shuttle vehicles and found them feasible, though less efficient for delivering lunar payload than, for instance, a nuclear stage. This memorandum suggests that such high energy shuttles deserve further study, since it appears that in a low budget program, an optimized shuttle orbiter-expendable booster combination could offer a complete, cislunar manned space flight capability pending the development of space tug, nuclear stage, and space station.

In current NASA studies, the second stage shuttle orbiter is a high lift to drag ratio, lifting body with a payload of about 50,000 lbs. to low orbit. Recent work at Bellcomm and elsewhere has considered a variety of alternate configurations. This leads one to ask whether there are also alternate missions. A second stage shuttle orbiter must provide a ΔV of perhaps 18,000 ft/sec, deliver payload in Earth orbit, deboost, dissipate the 25,000 ft/sec of velocity by aerodynamic braking and land. If a fully fueled orbiter can be placed in Earth orbit, the performance requirements for high energy missions are of this same order.

Table I

Mission		ΔV ft/sec
I	Earth Orbit Insertion	∿18,000
II	100 nm Earth Orbit to Synchronous Equatorial Orbit and Deboost	∿20,000
III	Earth Orbit to Low Lunar Parking Orbit and Trans-earth Injection	∿16,000

In each case the return is by aero braking either to Earth or by apogee kick to low, circular Earth orbit. Because of the high structure weight of lifting body vehicles, these missions would require delivery of substantial amounts of fuel to Earth orbit. Therefore, a ballistic entry vehicle which lands vertically would be preferred. Propulsion for vertical earth landing is perhaps a thousand feet per second additional. Given a propulsive, vertical lander, a fourth possible mission can be considered: a LM/B type shuttle from lunar orbit to lunar surface and return.

Table II

Mission		ft/sec
IV	Lunar Orbit to Lunar Surface and Return	14,000

The high energy shuttle requires a heat shield for the higher entry velocity of 36,000 ft/sec, and would need more heat shield refurbishment than current shuttle concepts.

A preliminary sizing analysis has been performed. Mission profiles are sketched in Figures 1 and 2, and the results are shown in Table III. No parametric analysis has been made. The gross weight of the vehicle including payload was assumed 150,000 lbs., consistent with insertion to orbit by an S-IVB-solid rocket motor vehicle. A propellant fraction (the ratio of propellant weight to gross weight excluding payload) of 0.80 was assumed. The engine is assumed a high chamber pressure hydrogen oxygen engine of specific impulse 460 seconds. The round trip to lunar orbit was the sizing mission with a total ΔV of about 17,200 ft/sec. The mass ratio for this mission is 3.2 to 1. The inert weight of the vehicle is about 26,000 lbs. and the round trip payload is 21,000 lbs.

As summarized in Table III, this vehicle carries a 10,000-lb. payload on the round trip to synchronous orbit. Used as a second stage carrying 21,000 lbs. to Earth orbit, a single solid rocket motor is required; a 5-segment, 156-inch solid rocket motor weighing 1.6 M lbs. appears to be adequate.*

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*Five flights of this shuttle/SRM are necessary to re-fuel the orbiter, if this were considered an alternate to the S-IVB/SRM launch.

The lunar surface mission of Table III carries over 9,000 lbs. of payload to the lunar surface and return. The vehicle is stored in lunar orbit and requires two logistics flights to bring the crew and re-fuel it. Return to Earth is by LOR with one logistics vehicle. A dual mission -- orbital tanker and lander, both returned to Earth -- is marginal, but might well be a preferred mode for optimized vehicles and trajectories.

These numbers are intriguing enough to warrant further study. It appears that a vigorous manned space flight program could be pursued for several years on the basis of a single major development plus the qualification of the low cost boosters. The lunar capability is substantial compared with Apollo. Functions such as satellite servicing, if desirable, could be pursued in any cislunar orbit and the flight of up-down payloads to low earth orbit would provide experience with a type of manned space flight payload not feasible in the Skylab Program. Important technical requirements on the shuttle beyond those now considered are the high velocity entry, a longer active life -- times of up to a month are probably required for meaningful lunar and low earth orbit missions -- and a requirement for passive orbital storage. In addition, the launched weights are more attractive and the lunar surface mission is feasible only in the case of a ballistic, vertical landing vehicle.

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Attachments
Figures 1 and 2

Table III

MISSIONS AND PERFORMANCE

Assumes: Gross Weight 150K #; Isp, 460; propellant fraction, $0.8 = \frac{\text{propellant weight}}{\text{propellant + inert weight}}$.

Mission IIIA used for sizing: propellant weight 103K #; inert weight, 26K #.

	I Earth to Orbit	II E/O to Synchronous Equatorial	III E/O to Lunar Orbit	IV Lunar Orbit to Lunar Surface
ΔV ft/sec	Gravity, Drag 4,000 Ascent 25,600 Deboost 500 Hover and Land 1,000 31,100	First Impulse 8,100 Equatorial Synchronous Insertion 6,000 Deboost 6,000 Hover and Land 1,000 21,100	TLI 10,200 LOI 3,000 TEI 3,000 Land 1,000 17,200	Down 6,900 Up 6,900 13,800
P/L K's of Lbs.	**Mode A** SRM launch of shuttle orbiter sized by Mission III: SRM ΔV=31,100 ft/s − 17,200 ft/s = 13,900 Isp 250 and λ' of 0.9: 1.6M # SRM is required. **Mode B** S-IVB/SRM launch: 150K gross weight in orbit.	Payload A. Round Trip 10K # B. Up Only 16K # (Shuttle returns with zero payload)	Sizing Mission Payload A. Round Trip 21K # B. Delivery Only 27.5K # C. Return Only 87.5K #	(See Figure 2) Shuttle stored in lunar orbit. Two resupply vehicles bring 55K # of propellant. Payload A. Round Trip 9.7K # B. Delivery Only ~50K #

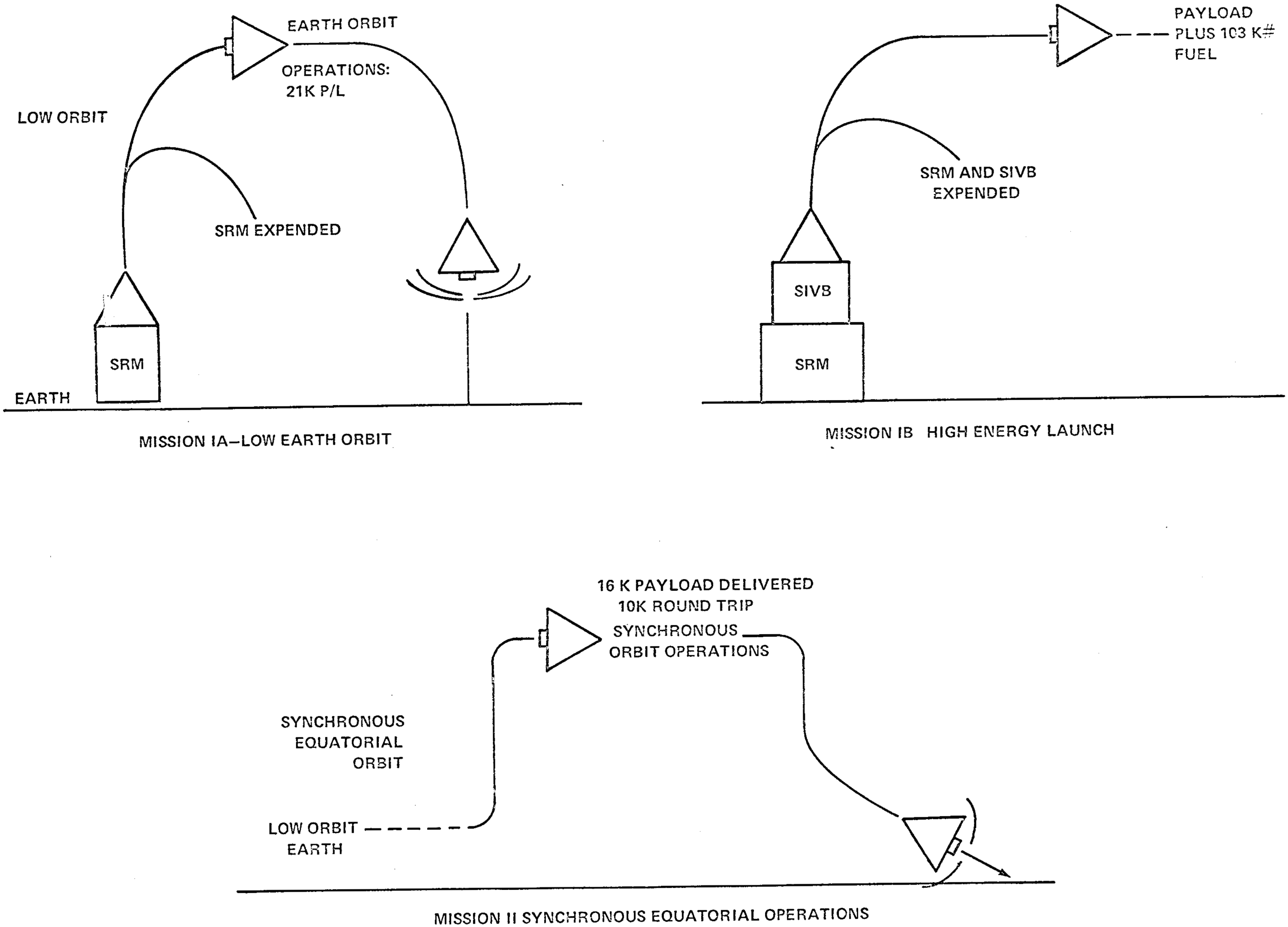

FIGURE 1 - EARTH ORBIT MISSION PROFILES

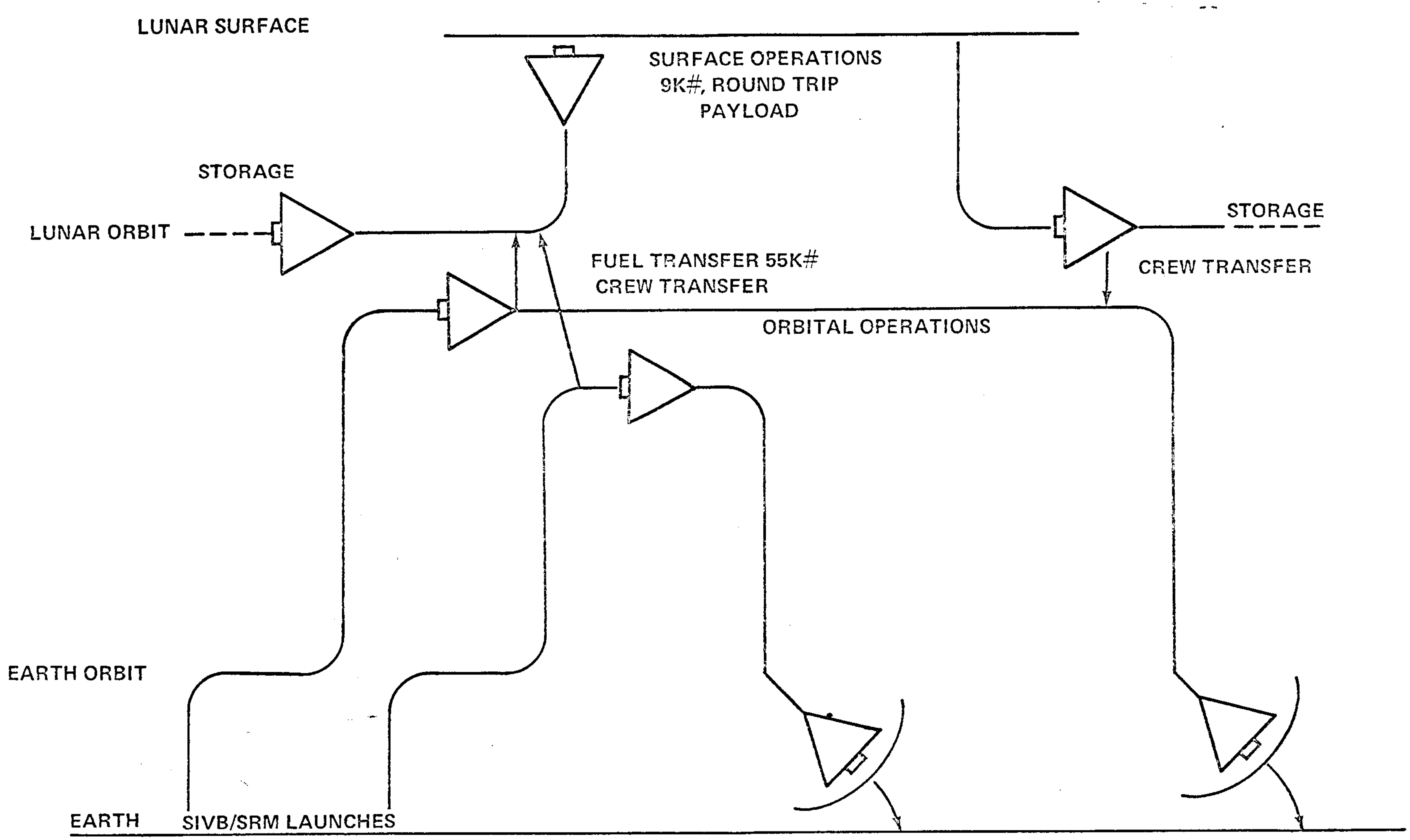

FIGURE 2 - LUNAR OPERATIONS